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ABRASIVE TOOL MADE OF SILICON CARBIDE MICROPOWDERS ON A CERAMIC BINDER

A. N. Krasnov[1] and A. M. Tsyv'yan[1]

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The processes that take place in silicon carbide microabrasive powders in firing of abrasives were examined and the effect of the granulometric composition of the powders on the properties of the articles were investigated. The possibility of obtaining articles of a given hardness using micropowders of different granulometric composition was demonstrated.

The abrasive tool made of microabrasive silicon carbide powders on a ceramic binder is used for the concluding operations in precision treatment (superfinishing and honing) of metals and high requirements are imposed on the quality of this tool. Obtaining a tool with stable properties is the basic problem in the manufacturing process in fabrication of an abrasive tool from such powders. The analysis of the parameters of the manufacturing process showed that the difference in the properties of the tool is especially marked when powders from different manufacturers are used. Monitoring the powders for compliance with the technical requirements showed that with an identical chemical composition and contaminant content, the materials differ in granulometric composition and the articles made from them have a different degree of hardness in the same conditions.

We investigated the properties of abrasive articles made of silicon carbide micropowders with hardness of M7 and M10 and different granulometric composition. The change in the properties on heating in the conditions of firing the tool was examined and the characteristics of the articles were determined in several firing modes.

According to the technical requirements for granulate and the methods of controlling grinding materials (GOST 3647), the content of particles of the basic fraction in microabrasive powders is 40 – 45%. The content of particles of the limiting size (minimum and maximum fractions) should not exceed 5 – 10%. The content in the complex fraction consisting of particles of the basic and contiguous fraction (the grain size in the contiguous fraction should not be smaller than the grain size of the small fraction nor larger than the grain size of the basic fraction) should be 57 – 67%. However, powders from different lots and especially different manufacturers differ significantly on these indexes.

[1] Abrasives and Grinding Co., St. Petersburg, Russia.

The differences in the granulometric composition of the materials affect the specific surface area of the material, but it is not always possible to establish an unambiguous correlation between the specific surface area and the grain composition (Table 1). It is probably necessary to not only consider the grain size, but also the grain shape and character of the surface. The data on the content of the fractions in silicon carbide microabrasive powders with granularity M7 and M1 are based on a microscopic analysis of the materials and the results of measurements on a laser diffraction granulometer. A comparison of the grain composition and cutting power of the investigated samples of silicon carbide shows that the cutting power is determined not by the content of the basic fraction alone. These materials differ in cutting power with a close content of basic fraction, and a high content of large grains (Sample 3) almost always increases the cutting power of the material.

The effect of the granulometric composition on the hardness of the abrasive articles was examined in samples of silicon carbide microabrasive powders with granularity of M10. The samples were prepared by the standard manufacturing process, and the formulation of the samples was selected in consideration of the previously developed formulations for production of articles with M3 hardness in semidry molding with a 42% volume content of the abrasive material with a standard clay and feldspar ceramic binder.

The tested samples of silicon carbide with M10 granularity had an almost identical content of basic fraction but differed in the content of the other fractions (see Table 1). According to the data from measurements of the grain composition on a laser diffraction granulometer, the content of small and limiting fractions was approximately 10% in Sample 1, the content of the small fraction was 9% in Sample 2, and particles close to the size of the small fraction predominated

TABLE 1

Sample	Material	Silicon carbide microabrasive powder with a content of the fraction, ± 5%				Specific surface area of material, cm^2/g	Cutting power, g/min
		small	complex (basic + contiguous)	basic	limiting + large		
			With granularity M10				
1	M10	5	70	45	20	3500 – 5000	0.017 – 0.020
2	M10	9	75	40	16	5000 – 7000	0.016 – 0.017
3	M10	9	61	40	30	4700 – 5000	0.024 – 0.026
			With granularity M7				
4	M7	5	70	45	25	8500	0.015
5	M7	8	72	40	20	9500	0.014
6	M7	15	75	35	10	13,000	0.011
7	M7	12	80	35	8	10,000	0.011

in the contiguous fraction; the content of the limiting fraction in this sample was approximately 5%. In Sample 3, the content of the small and limiting fraction was approximately the same, and the particles of the contiguous fraction were larger than in Sample 2.

A difference in the granulometric composition of the abrasive materials used affects the rheological properties of the molding pastes in molding articles. For molding articles with a given density, we experimentally selected the molding pressure and moisture content of the pastes. In the case of Material 2 with a high content of the small fraction, the molding pressure was 1.5 – 2 times higher than the standard pressure. When Material 3 with a high content of the large fraction was used, it was necessary to reduce the moisture content of the pastes, and the molding pressure was approximately 1.5 times lower than the traditional pressure.

All of the items were dried and fired in the same conditions. The samples were controlled for hardness by the acoustic method and the ball depression method on a Rockwell instrument. The properties of the samples after firing are reported in Table 2. For almost the same weight of the articles before firing, the degree of hardness and density of the samples differed significantly. The hardness and sound velocity in the samples made of Materials 2 with a high content of the small fraction were higher than in the samples made of Material 1. The hardness of the articles made from Material 3 was also higher than for the samples from Material 1.

TABLE 2

Sample	Sound index	Instrument readings* (GOST 19202)	Density of sample after firing, g/cm^3	Degree of hardness
1	31	81 – 95	1.584	M3
2	35	100 – 105	1.626	C – CT
3	37	98 – 108	1.628	C – CT

* For a bead diameter of 5 mm and load of 981 N.

A comparison of the oxidizability of silicon carbide microabrasive powders with granularity M10 and M14 (thermogravimetric method) showed that oxidation of the silicon carbide begins at 660°C and is not only a function of the SiC content but also the size of the grains in the material. With an increase in the free carbon content and a decrease in the particle size, the intensity of oxidation increases and the amount of oxidized material soluble in hydrofluoric acid increases.

As a result of the x-ray diffraction study of silicon carbide samples with granularity of M7 and M10 after heat treatment, it was found that the silicon carbide grains are oxidized, and the silicon dioxide formed undergoes a polymorphic change during firing and is transformed into cristobalite. This is due to volume changes and can lead to cracking of the articles in firing the micropowder abrasive tool.

The results of determining the change in the proportion of the material soluble in the acid are reported in Table 3. The studies showed that in materials with a high content of small fractions, the degree of oxidation of the grains in heating to the firing temperatures can exceed 50%. Published sources show that the curve of the change in oxidized pure silicon carbide on heating to 900°C is parabolic in character, and a phase transition of the oxidized layer of SiO_2, which is considered protective, then takes place.

The content of the soluble part in articles made of the investigated materials was determined to estimate the degree of destruction of silicon carbide grains with different granulometric compositions. The content of the soluble part in the articles was 30 – 38%, which is almost in agreement with the calculated data with consideration of the additive properties of the binder and SiO_2 formed in oxidation of the silicon carbide grains. This probably suggests that in the conditions of firing abrasive articles on a ceramic binder, formation of silicon oxide is not protective but some of the SiO_2 passes into the binder and some is converted into cristobalite due to the presence of sodium- and potassium-containing feldspars in the binder.

TABLE 3

Material	Specific surface area, cm^2/g	Firing temperature, °C	SiO_2 content in powder, %
M7	13,500	–	1.4 – 0.7
Content of particles < 4 μm		1000	15.0 – 18.0
in size of ~ 30%		1100	36.0
		1200	58.0
M7	8500	–	0.2
Content of particles < 4 μm		1100	33.0
in size of ~ 5 – 7%		1200	51.0
M10	5600	–	0.9
Content of particles < 5 μm		1000	5.5
in size of ~ 20 – 30%		1100	13.0
		1200	29.0
M10	4300	–	0.5 – 0.7
Content of particles < 5 μm		1100	11.5
in size of ~ 5 – 7%		1200	25.0

TABLE 4

Formulation	Firing temperature, °C	Sound index (GOST 25961)	Instrument readings* (GOST 19202)
1	1150	25	30 – 35
1	1200	27	45 – 55
1	1240	33	81 – 95
2	1150	31	65 – 82
2	1200	33 – 35	80 – 90
2	1240	37 – 39	100 – 105
3	1150	31	70 – 82
3	1200	33	82 – 95
3	1240	37	98 – 108
2-1	1150	27	70 – 80
2-1	1200	33	81 – 93
3-1	1150	33	80 – 92
3-1	1200	35	85 – 95

* For a 5 mm bead diameter and 981 N load.

The data for samples of silicon carbide articles with granularity of M10 are reported in Table 4. The difference in the weight of the samples of abrasive articles fired at different temperatures indicates the effect of the firing regime on the degree of oxidation of the silicon carbide microabrasive powders. The weight of samples of the same composition increased proportionally to the firing temperature. The articles obviously become denser.

The hardness of the samples is a function of the firing temperature, and the hardness increases with an increase in the temperature. For a high small-fraction content in the material, the pore size in the samples is smaller than in the other two cases. In addition, in firing articles made of Material 2 with a high content of the small fraction, the silicon carbide is oxidized more intensively, with formation of silicon oxide grains in the contact zone, which makes the samples dense and strong. For a high content of the large fraction (Material 3), the articles have higher hardness indexes than the articles made of Material 1.

To obtain articles from Materials 2 and 3 with the same hardness as articles from Material 1, a second series of samples with a reduced volume content of abrasive material (40%) was prepared — formulation 2-1, and samples with a high binder content was prepared for articles from Material 3 — formulation 3-1. Firing was conducted at 1150 and 1200°C. A comparison of the hardness of the samples of this series shows that at a high content of the small fraction, which is prone to oxidation, the samples have high hardness, and the hardness varies when the volume content of the material changes. An increase in the binder content affects the hardness of the articles to a small degree. It follows from the data in Table 4 that the firing temperature must be decreased to reduce the degree of the change in the abrasive grains during firing for materials with a high content of the small fraction.

The data obtained allowed determining the basic factors that affect the properties of abrasive articles made of silicon carbide microabrasive powders. Mandatory control of the granulometric composition of the silicon carbide powders is necessary in determining the formulation of the abrasive tool. The hardness of abrasive articles made from micropowders can be regulated by changing their density and firing conditions.